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A POLLEN DIAGRAM FROM "LAGUNA DE LA HERRERA" (SABANA DE BOGOTA)

BY

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INTRODUCTION

The Laguna de La Herrera (alt. ca 2550 m) is a lake situated on the western border of the Sabana de Bogotá, near Mosquera (dept. of Cundinamarca, Colombia) (fig. 2). This part of the Sabana has a relatively dry climate (appr. 600—700 mm rainfall), as it lies in the rain-shadow of the hills that border the Sabana on its western edge, and it bears therefore a xerophytic vegetation. The western slopes of the bordering mountains, that fall steeply to warmer valleys, have a much higher rainfall and are almost continuously clouded. They bear therefore a cloud-forest, of the Quercetum type, that reaches partly the very top of these mountains. Fig. 1 shows this in an idealized section. For further details on the mentioned vegetation-types, we may

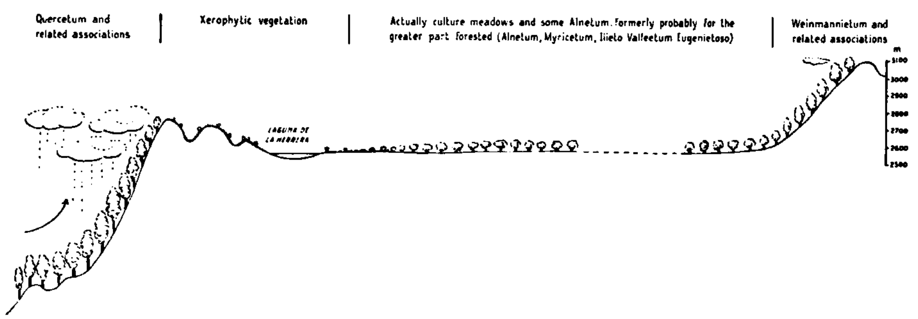

Fig. 1. Idealized section through the Sabana de Bogotá, showing potential vegetation types.

refer to van der Hammen & Gonzalez (1960). In the same publication the Geological history of the Sabana is shortly described, including the Quaternary history as a big lake with fluctuating water-level. Geological data on the area of Laguna de La Herrera were given in van der Hammen & Parada (1958). The present section of the pollen diagram corresponds approximately to bore-hole no. 19 of fig. 2 of that publication. The origin of the lake is probably (at least partly) due to fluvial erosion and sedimentation (old course of Rio Balsillas?). The lake sediments consist principally of diatom gyttja with intercalated layers of clay or peaty material. The base consists of hard greenish to white clay. We believe that this clay possibly corresponds to the altered clays that are exposed in the nearby hills, and which belong to much older eroded lake-sediments (see van der Hammen & Parada, 1958).

The only other existing pollen diagram from the Holocene of the Sabana is from near Bogotá, near the eastern border of the Sabana (section CUX upper part,

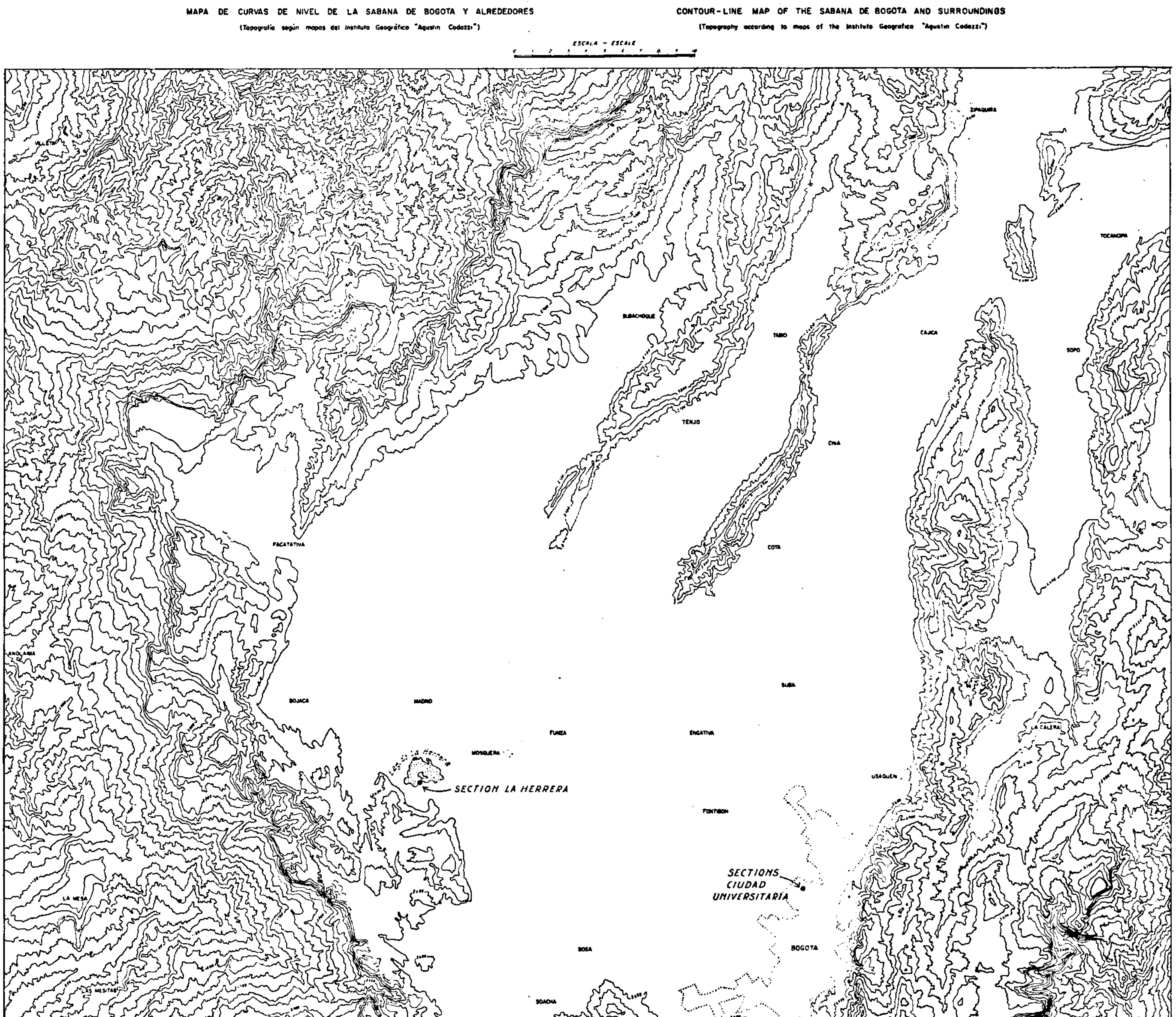

Fig. 2. Map showing the locality of Laguna de la Herrera on the Sabana de Bogotá.

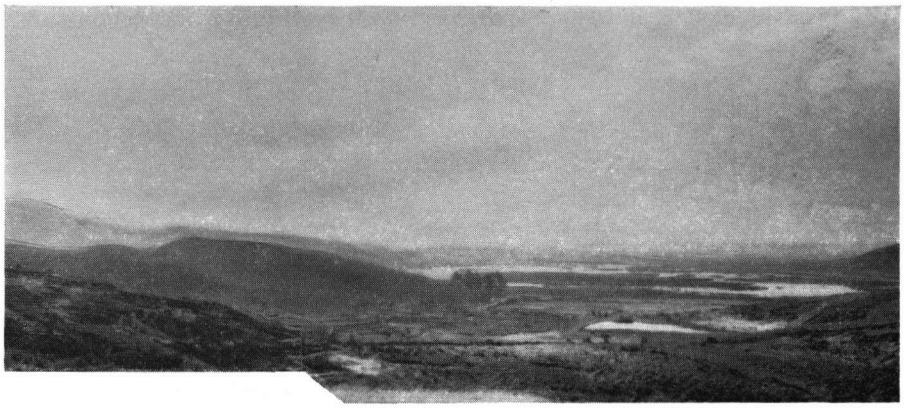

Fig. 3. Laguna de La Herrera.

fig. 7 of van der Hammen & Gonzalez, 1960). Nevertheless, that diagram shows a completely different picture, reflecting a local vegetation (it is not from lake-sediments), under much more humid conditions (alternation of Alnetum and Myricetum). A direct comparison of the diagrams of Bogotá and La Herrera is therefore difficult.

PRESENT VEGETATION

A large part of the area has a very low vegetation-cover, not higher than ca 20 cm. In this vegetation we may find Gramineae, *Ophioglossum nudicaule*, *Selaginella sellowi*, *Evolvulus*, *Plantago*, *Cardionema* (Caryophyllaceae), *Artemisia sodiroi*, *Malacocarpus* (Cactaceae) etc. Higher $\pm$ woody semi-shrubs, up to ca 80 cm, are *Solanum lycioides*, *Salvia bogotensis*, *Eupatorium leyvensis*, *Stevia lucida*, *Lantana* cf. *boyacana* and probably *Dodonaea*.

A characteristic element are the *Opuntia's* (Cactaceae), that may grow several meters high. Where sheet-erosion or-sedimentation has recently taken place, we find *Atriplex* (Chenopodiaceae) as a very abundant pioneer (germinating on wet sand and loam as fresh "wash"). *Cardionema* may grow under the same conditions, and eventually also *Heterospermum* (Compositae).

The lake itself is bordered by a zone of marsh vegetation, including *Juncus*, *Rumex*, *Polygonum*, *Jussiaea*, *Hydrocotyle*, etc.

Most of the area is subjected to grazing, and the vegetation has certainly suffered some changes. Soil-erosion ("quebrada" or "canon"-formation) is very extensive, and possibly caused by different influences of man (especially over-grazing, destruction of semi-shrub vegetation and disturbance of vegetation-cover) combined with periods of frequent sudden heavy rainfall (see below).

THE C 14 DATES

C 14 analyses were carried out by Dr. J. C. Vogel in the Groningen C 14 laboratory. Financial support for these analyses was received from the Netherlands Foundation For Pure Scientific Research Z.W.O.

The samples for pollen and C 14 analysis were all taken from one section sampled with a Dachnovsky sonde with a diameter of 5 cm.

C 14 *samples section Laguna de La Herrera*

Laboratory number	Sample number	Depth	Material	Age
GRN 4297	Col. 23	30— 40 cm	Clay with plant remains and charcoal	580 ± 60 yr (A.D. 1370)
GRN 4123	Col. 22	57— 72 cm	Diatom gyttja with plant remains	700 ± 65 yr (A.D. 1250)
GRN 4122	Col. 21	182—198 cm	Diatom gyttja with plant remains	2050 ± 50 yr (100 B.C.)
GRN 4005	Col. 20	405—417 cm	Diatom gyttja with plant remains	4700 ± 80 yr (2750 B.C.)
GRN 3606	Col. 19	445—455 cm	Diatom gyttja with plant remains	5020 ± 80 yr (3070 B.C.)

THE INTERPRETATION OF THE POLLEN DIAGRAM

The principal changes of the pollen curves of the pollen diagram (Plate I) are indicated on fig. 4. This table gives also the relation of these changes to the depth and to the age,the C 14 dates and a curve indicating the relative fluctuations of the lake-level.

The column of "calculated age" gives the ages calculated on the basis of the rate of sedimentation, derived from the total thickness of the sediments and the oldest C 14 date. We will discuss successively

a. the fluctuations of the lake-level.

b. the pollen zones (correlation with other diagrams from the Eastern Cordillera).

c. The local changes of vegetation (and the influence of man).

a. The fluctuations of the lake-level

Three intervals of low lake-level can be recognized from both the pollen diagram and the lithology. In the lithology they are reflected as peaty material intercalated in the diatom-gyttja. In the pollen diagram they are reflected as maxima in the curves of the plants from the marshy shore of the lake. These plants extended apparently over the lake-bottom as soon as the water-level was sufficiently low to permit that. The same phenomenon could be seen recently during years of (partly artificial) extremely low water-level. The mentioned plants belong to *Polygonum*, *Rumex*, Cyperaceae, Juncaceae, Chenopodiaceae, Umbelliferae, *Jussiaea* etc.

The periods of low lake-level were dated by C 14 analysis, and have ages of respectively ca 3100 B.C. — 2700 B.C., ca 100 B.C., ca A.D. 1250 and ca A.D. 1370.

It is interesting to compare these ciphers with those from periods of low lake-level

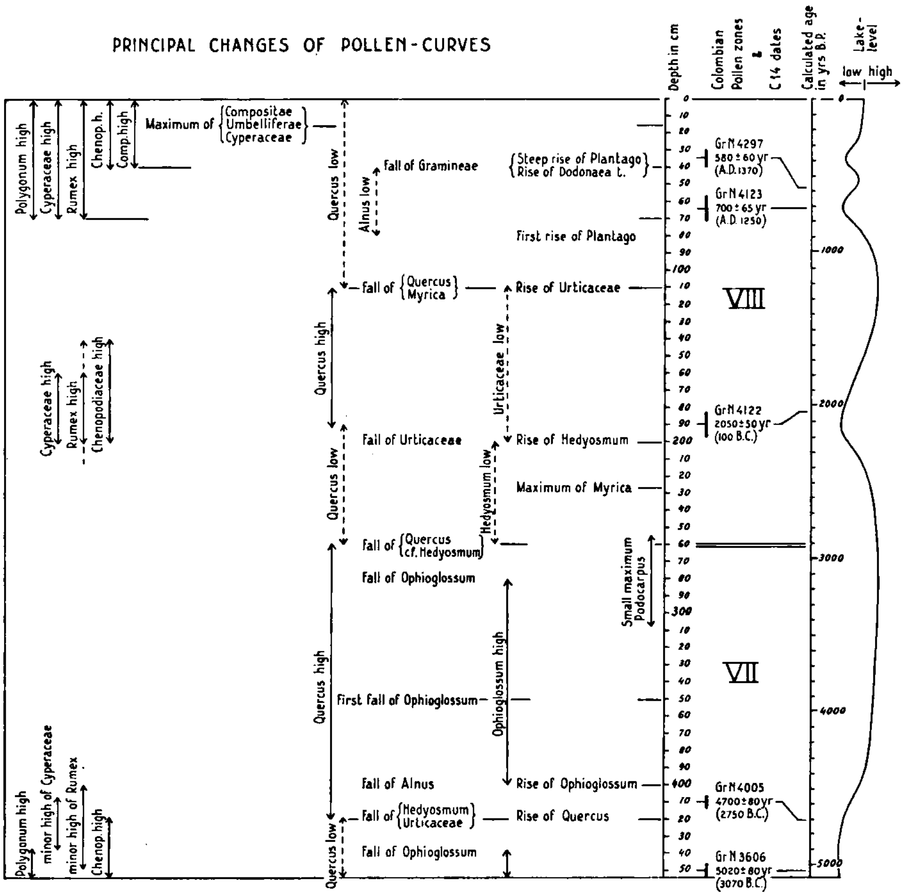

Fig. 4. Principal changes of pollen curves of the diagram Laguna de La Herrera, as related to depth, age and fluctuations of the lake-level.

in other parts of Colombia. In the tropical lower Magdalena Valley, between El Banco and Magangué, a section from the sediments of a big lake shows two peat-layers in a section of many metres of clay. Both the pollen diagram as the stratigraphic sequence show that both peat-layers represent periods of low lake-level (Wymstra, 1965). They have a C 14 age of respectively A.D. 1240 (GRN 2427) and A.D. 1480 (GRN 2425). These dates are remarkably similar to those dating the two youngest lower lake-levels of the Laguna de La Herrera. Another section of lake-sediments is from the Laguna de Agua Sucia in the tropical savannas of the Llanos Orientales. There is a peat-layer in the lake-sediments, indicating a low lake-level, with a C 14 date of 200 B.C. (GRN 4416) (Wymstra & v. d. Hammen, 1965). This date is very near to the middle peat-layer of the La Herrera section.

These facts strongly suggest that the low lake-levels were caused by dry periods of low precipitation over a wide area. Some of these dry periods may even be recognized in far separated parts of the world.

An example is that A.D. 1200 is a date for a "recurrence-horizon" in the

N.W. European peat-bogs, and many others are dated between 200 B.C. and A.D. 200 (Aletsee, 1963).

It is not quite certain, if the peaty layer at the base of the section of La Herrera means a dry period or not, or only a beginning inundation of the area of the lake. Nevertheless it is most interesting to remember that the date of ca 3000 B.C. corresponds to a date for the base of the peat in a mountain mire in Paramo de Palacio (W—781; van der Hammen & Gonzalez, 1960b), to the beginning of pollen zone VII of the Colombian Eastern Cordillera, and to the beginning of the Subboreal in Europe.

It is equally interesting to mention that the lower part of a pollen diagram from the Llanos Orientales, corresponding to zone VII, seems to reflect a drier savanna-climate (Wymstra & van der Hammen, 1965).

b. The pollen zones

The pollen diagram shows the reflection of a rather local vegetation-picture, from the local xerophytic vegetation. For that reason it is not easy to apply the Colombian Cordilleran pollen zonation to this diagram. Nevertheless, the curves of some of the wind-flowering trees show a number of characteristic fluctuations, comparable to those from the uppermost zones of other diagrams from the Cordillera Oriental, and the correlation on this basis is supported by the C 14 dates. These curves are those of *Quercus* (oak) and *Podocarpus*, and partly those of *Alnus* and *Hedyosmum* (see fig. 4 and plate I).

The *Quercus*-curve corresponds in general course with that from Paramo de Palacio (van der Hammen & Gonzalez, 1960*b*) and also with that from Laguna de Los Bobos (van der Hammen, 1962).

There is only a difference in the percentages, which are in general lowest in the Paramo de Palacio area, where no *Quercus* is growing, higher in the Laguna de La Herrera area, very near to an area with forest of the Quercetum type (fig. 1), and highest in Laguna de Los Bobos, situated immediately above a Quercetum area. In zone VII *Quercus* is relatively high, with a tendency to be lower in VII a and high in VII b. There is a marked fall of the *Quercus*-curve in the beginning of zone VIII, and a second maximum is present somewhere in the middle of zone VIII. The *Podocarpus* curve shows a (low) maximum in zone VII, and specially in the second part of this zone.

The *Alnus* curve is high in zone VII a and low in VII b.

The curve of *Hedyosmum* may show a minimum in the beginning of zone VII (Laguna de Los Bobos only).

Because of all these reasons, we may conclude that our diagram represents pollen zones VII and VIII, and that the limit of the two zones is situated at a depth of approximately 260 cm. The base of the diagram should correspond approximately to the beginning of zone VII.

In fig. 4 the C 14 dates are indicated, and also the calculated age corresponding to every depth. This calculated age is based on the average rate of sedimentation, calculated from the date and the depth of the C 14 sample at the base of the section (ca 9 cm per 100 yr), and corresponds closely to the other C 14 dates.

The calculated age for the base of zone VII is 2900 yr B.P., corresponding closely to other C 14 dates or calculated age for the base of zone VII from other pollen sections (van der Hammen & Gonzalez, 1960b and 1965; Gonzalez, van der Hammen & Flint, 1965; van der Hammen, 1962).

c. The local changes of vegetation and the influence of man

Most of the pollen spectra of the diagram show a rather high Gramineae-percentage. In zone VII it fluctuates between 25 and 50 % and in zone VIII (except the upper 4 spectra) between 35 and 60 %. The relatively high Gramineae-percentage at this altitude is a local phenomenon, due to the fact that the surroundings of the lake bear a xerophytic open vegetation and not a closed forest cover, as would correspond to this altitude under more humid conditions (fig. 1). Under these circumstances it is doubtful if the Urticaceae should be included in the "forest-belt elements", as what we would like to see reflected in the diagram is the relation of open xerophytic vege-tation to closed forest. We do not know if the Urticaceae pollen was produced in both of these vegetation-units or not.

However, if we would exclude the Urticaceae from the sum, the course of the Gramineae-curve would not change fundamentally.

Pollen of typical plants of the xerophytic vegetation is not very abundant, due to the fact that most of them are not wind-pollinating (Solanaceae, *Evolvulus* etc.), or could not be recognized as a genus (Compositae). An exception makes *Ophioglossum nudicaule*, especially common between 280 cm and the bottom of the section. It is not clear why the spores of this plant are almost lacking in the upper 280 cm of the section. Once we know more on the ecology of this species an explanation of this astonishing fact may be found.

The most significant change of the vegetation is reflected in the upper part of the diagram, especially the upper 40 cm of the section. The interpretation of this interval is of importance for the understanding of the present vegetation. Moreover it may learn us about the influence of man on the vegetation, and give us data on the time of its presence in the Sabana. For these reasons we will discuss this part of the diagram a little more in detail.

At a depth of 110 cm there is a curious and marked change in the composition of the pollen of forest plants. The *Quercus*-curve falls definitely. There is also a decline of *Alnus* and *Myrica*, and a very marked rise of the Urticaceae. The date of this phenomenon should be approximately A.D. 750 (see fig. 4). We do not know with certainty the cause of these changes. It may be partly climatic, eventually together with a certain human influence. The presence of man on the Sabana de Bogotá shortly after that time is proved by a still unpublished C 14 date (GRN 4004) corresponding to the early Chibcha-culture (Duque Gomez). At a depth of 80 cm, when the *Quercus*-curve has reached a minimum, there is again a steep fall of *Alnus*, reaching now the lowest values of the diagram. At the same time the *Plantago*-curve starts to rise. The date of this level should be approximately A.D. 1050 (fig. 4). It marks apparently the beginning of a more important human influence.

At a depth of 40 cm, there is again an important change of the vegetation. The *Plantago*-curve rises steeply to a high percentage, the *Alnus*, *Hedyosmum*, Urticaceae and *Dodonaea*-type curves also rise, while the Gramineae show a sharp decline. It seems that the Gramineae pollen were in some way "replaced" by the *Plantago* pollen. Abundantly charcoal is found at this level, with a C 14 age of A.D. 1370 (The "calculated age" differs in this case slightly, with an age of ca A.D. 1500–1550). There seems to be no doubt that this change of vegetation was caused by man. The replacement of Gramineae by *Plantago* eventually might be caused by burning or grazing. The sharp decline of *Plantago* and rise of Gramineae in the uppermost sample indicates that the influence changed in more recent times. It is interesting to note that a few pollen grains of *Opuntia* were only found in the upper 40 cm of the section. It will be clear that the rise of the total of forest-elements in the general diagram of these upper 40 cm is principally caused by the decline of Gramineae (and its "replacement" by *Plantago*). Including *Plantago* in the pollen sum (and representing it in the main diagram together with the Gramineae), would have given a more satisfactory diagram-picture. We may resume that the influence of man on the vegetation near the Laguna de La Herrera was considerable, and it seems that elements like *Dodonaea*-type, *Plantago* and *Opuntia* were not present in any appreciable quantity before that time.

CONCLUSIONS

We may resume the above in the following conclusions. The Laguna de La Herrera (alt. 2550 m) exists since some 5000 years ago, and the sediments represent the Colombian Cordilleran pollen zones VII and VIII. The age of the limit of the two zones is approximately 2900 years B.P. The pollen diagram reflects fluctuations of the composition of the forest (outside the area of xerophytic vegetation) of the xerophytic vegetation itself and of the local marsh-vegetation around or in the lake. The lake-level was low between ca 3100—2700 B.C., around ca 100 B.C., A.D. 1250 and ca A.D. 1370. Peaty sediments were deposited and the marsh-vegetation extended over the lake-bottom. These intervals correspond to dry periods, and are also found in the tropical Lower Magdalena-valley or in the tropical Llanos Orientales.

A considerable percentage of the surface in the area must have been covered with open vegetation (at least during the last 5000 years), with grass as the principal wind-flowering component.

Human influence on the vegetation was important. It may eventually start already around A.D. 750, but anyhow around A.D. 1050, and eventually favoured by the dry climate around A.D. 1250. The human influence increases considerably around A.D. 1350. There is burning in the area, and *Plantago* invades the grass-vegetation. Human influence together with a minor dry period seem to have favoured the increase of certain xerophytic elements (*Dodonaea*-type, *Opuntia*).

Fig. 4 resumes the principal changes of vegetation, the depth-time relation, C 14 dates and the fluctuations of lake-level.

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